

Temporal Characterization of Zernike Decomposition of Atmospheric Turbulence

Adam Snyder
Stanford University, Stanford, CA

Introduction

Atmospheric turbulence limits the performance of ground-based surveys the future Large Synoptic Survey Telescope (LSST), which uses an active optics system to achieve optimal image quality. Currently LSST estimates the covariance matrix of the Zernike polynomial coefficients using a simulation of atmospheric turbulence. Using atmospheric turbulence data obtained from by the Gemini Planet Imager (GPI), a telescope located on Cerro Pachon, the site of LSST, the relevant covariance for the LSST wavefront sensors can be calculated and compared to the simulations. This analysis will also identify the presence of deviations from the Kolmogorov and Taylor frozen-flow models.

Research

The GPI AO system measures the instantaneous wavefront every millisecond and performs correction using two deformable mirrors (DM). Using the DM telemetry data, a time series of pseudo open-loop phase maps are reconstructed from the closed-loop residual phase maps, and the DM commands.

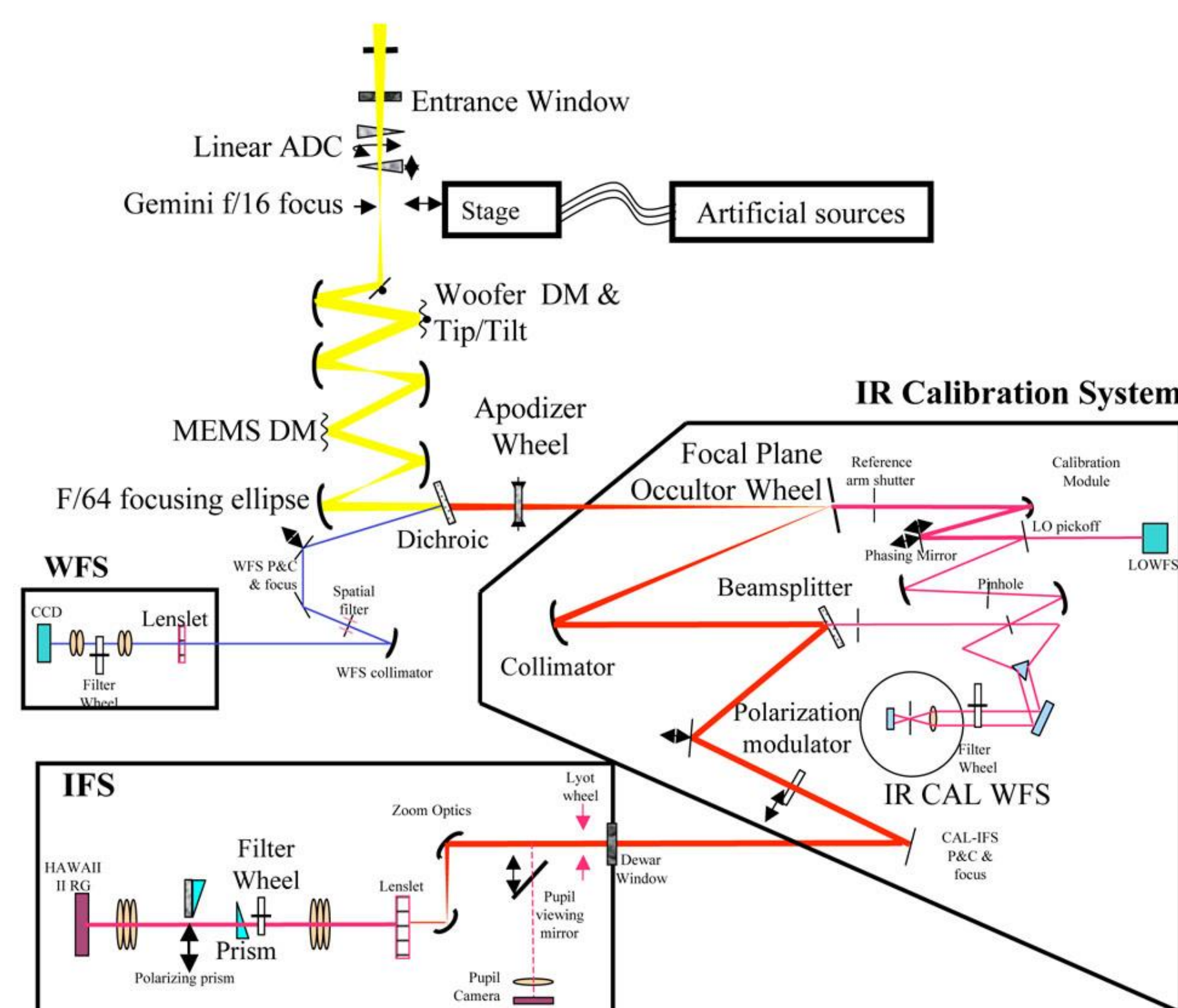


Figure 1 – Diagram of the GPI adaptive optics system.

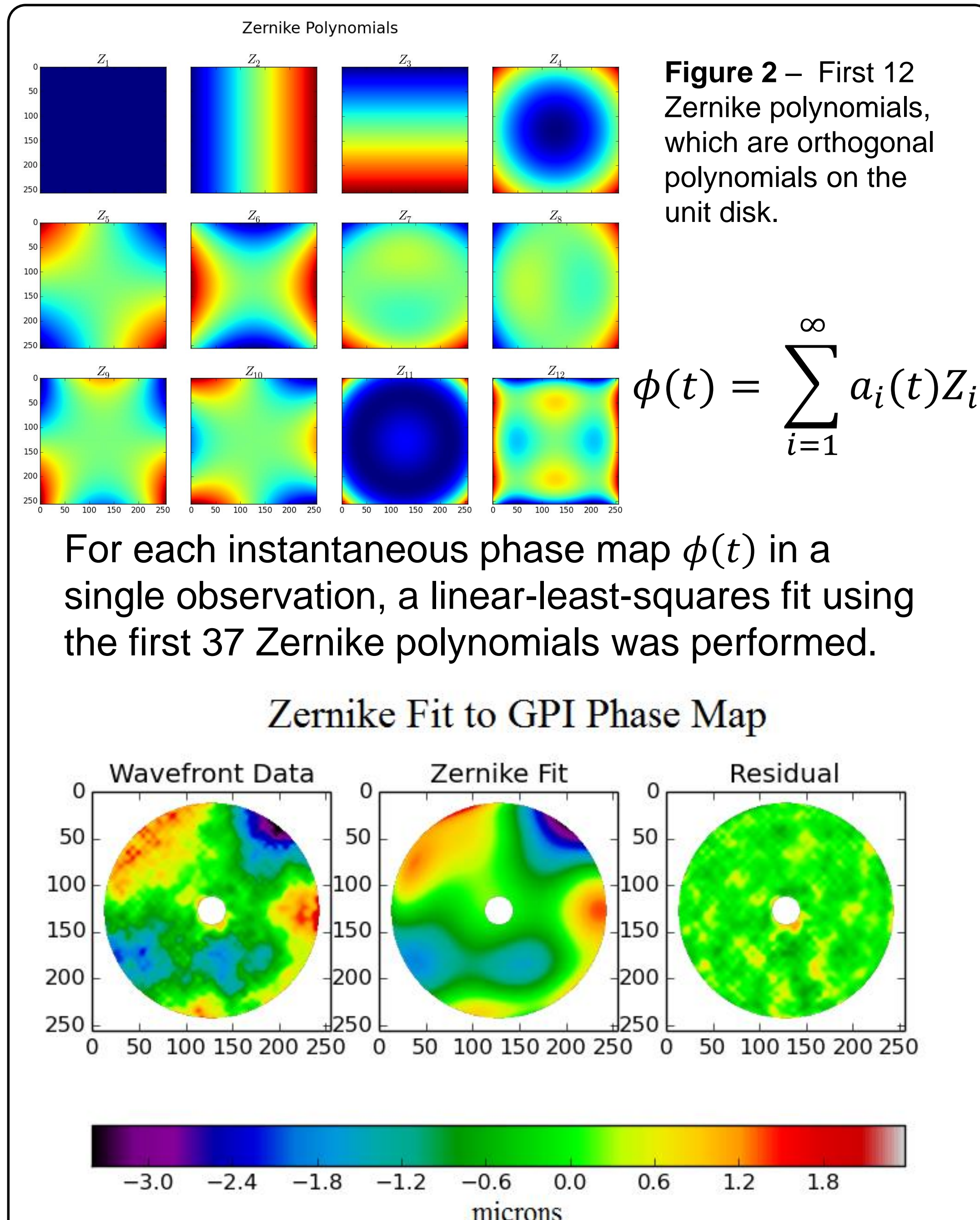


Figure 3 – Example of instantaneous phase map Zernike fit and residual with GPI pupil mask applied.

The process was repeated for simulated turbulence phase maps using the Kolmogorov and frozen flow models. It is easy to see that there appears to be significant longer period oscillations in the data, that are not captured in the simulation.

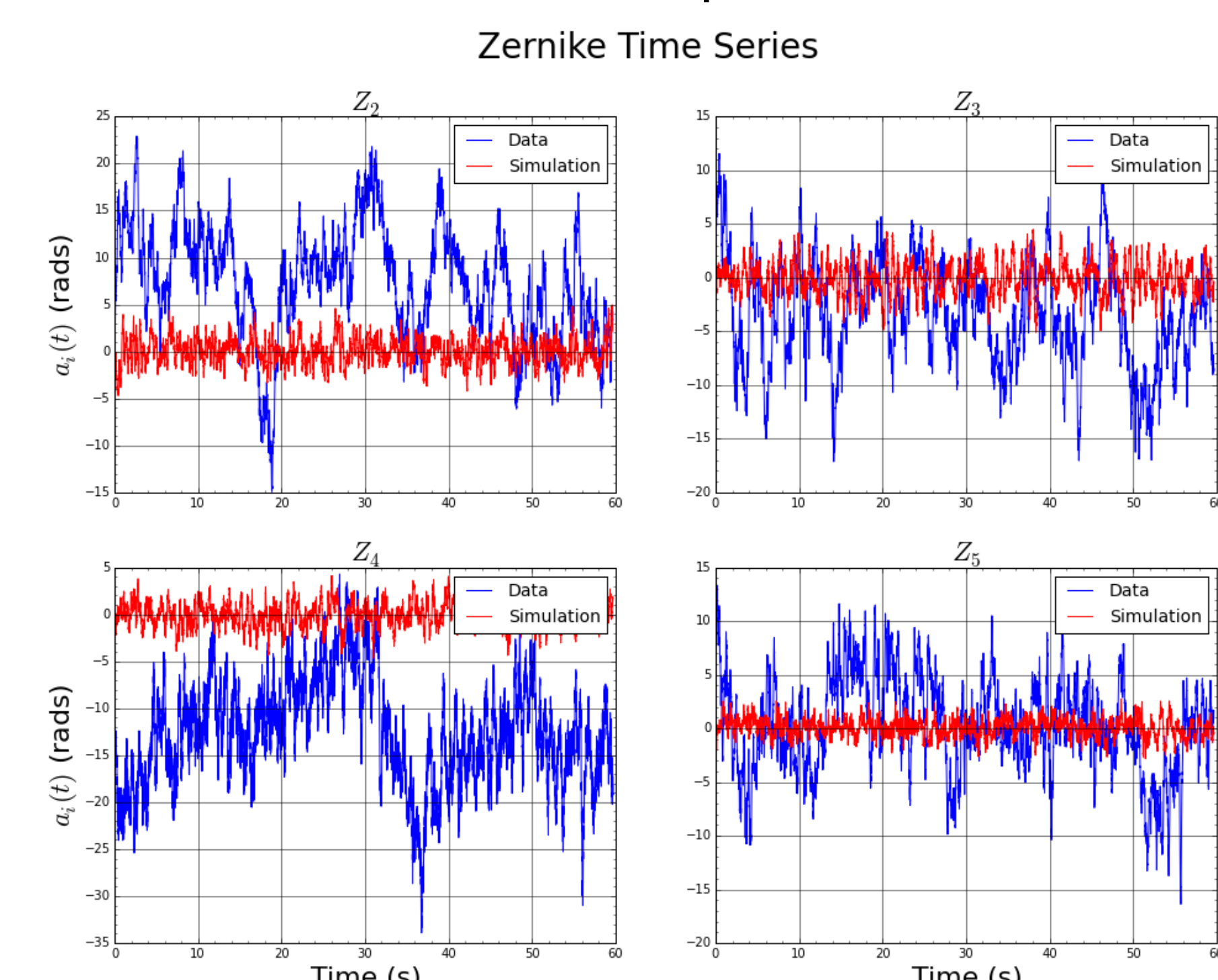


Figure 4 – First 4 Zernike coefficient time series (not including piston), comparing data and simulations

The Zernike periodograms can be calculated from the time series. The peak at 60 Hz is a known problem in the GPI AO focus correction.

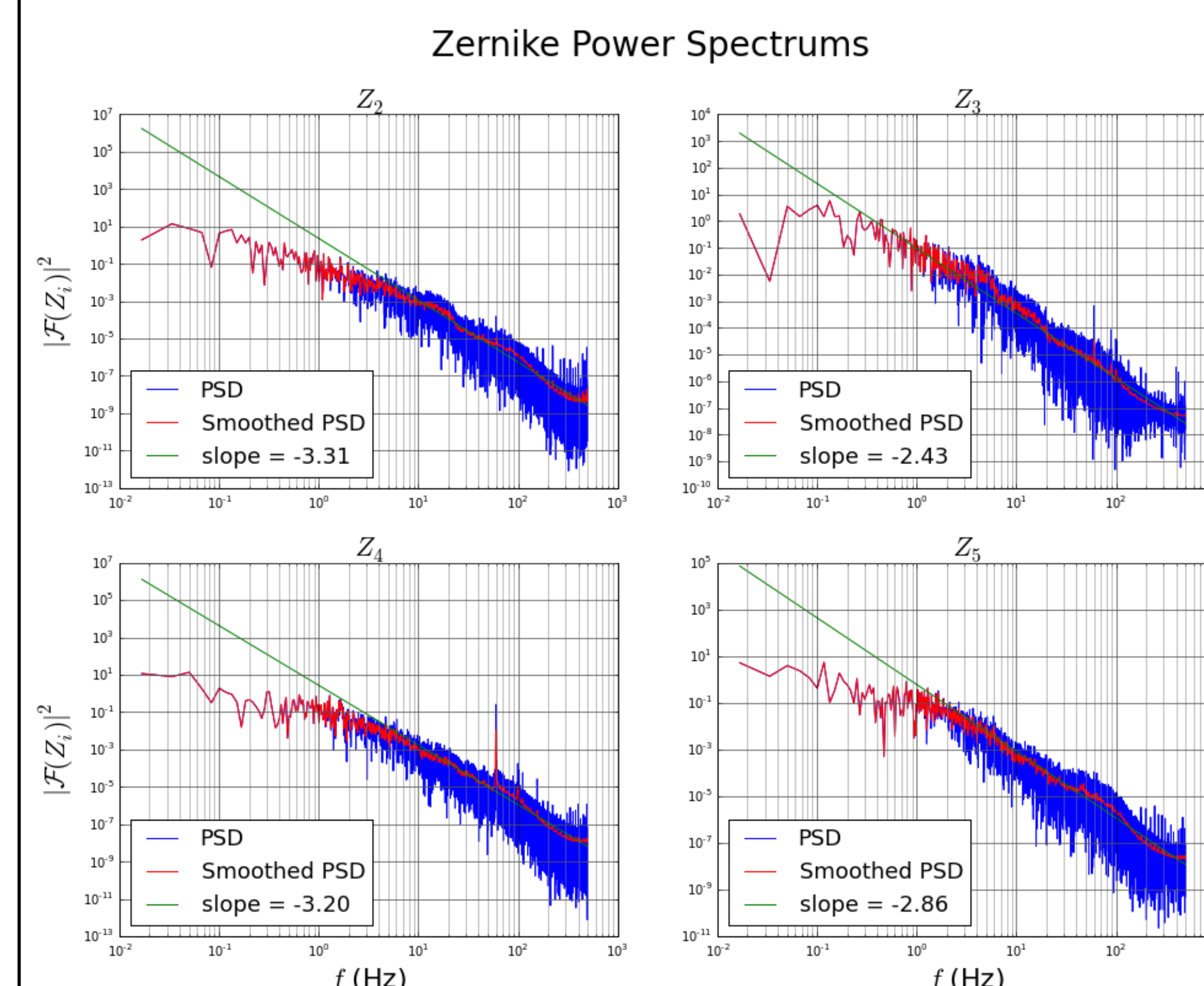


Figure 5 – First 4 Zernike periodograms (not including piston). Including is a smoothed curve and fit, depicting the power exponent.

Comparing to the simulation, the power exponents of the data Zernike coefficients are less than those of the simulation. An analytic model developed by Francois Roddier is also shown. Here the deviations in power exponent are most noticeable.

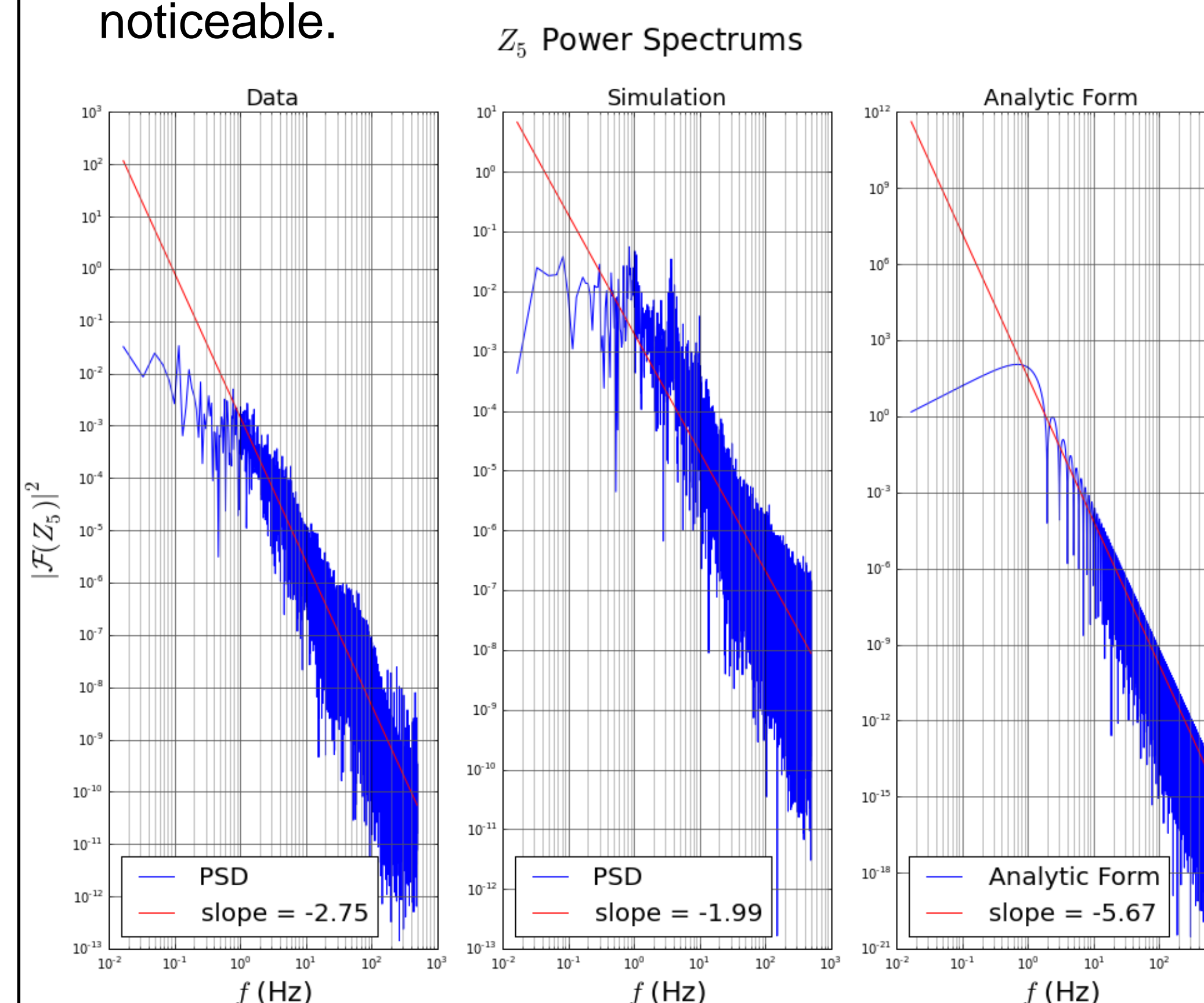


Figure 6 – Periodograms for Z_5 , oblique astigmatism, for data, simulated Kolmogorov turbulence, and the analytic form of the Z_5 power spectral density.

Conclusions/Results

The most noticeable contrast between the measured turbulence and simulated turbulence is in the amplitude of the Zernike variances. The data shows a long time variation in the mean of the Zernike coefficients that may be due to non-Kolmogorov behavior or may be introduced in the telescope optics. Non-Kolmogorov behavior was observed as a deviation in the predicted power exponent of the Zernike power spectrums, showing the pure Kolmogorov simulation may not accurately reflect the atmosphere.

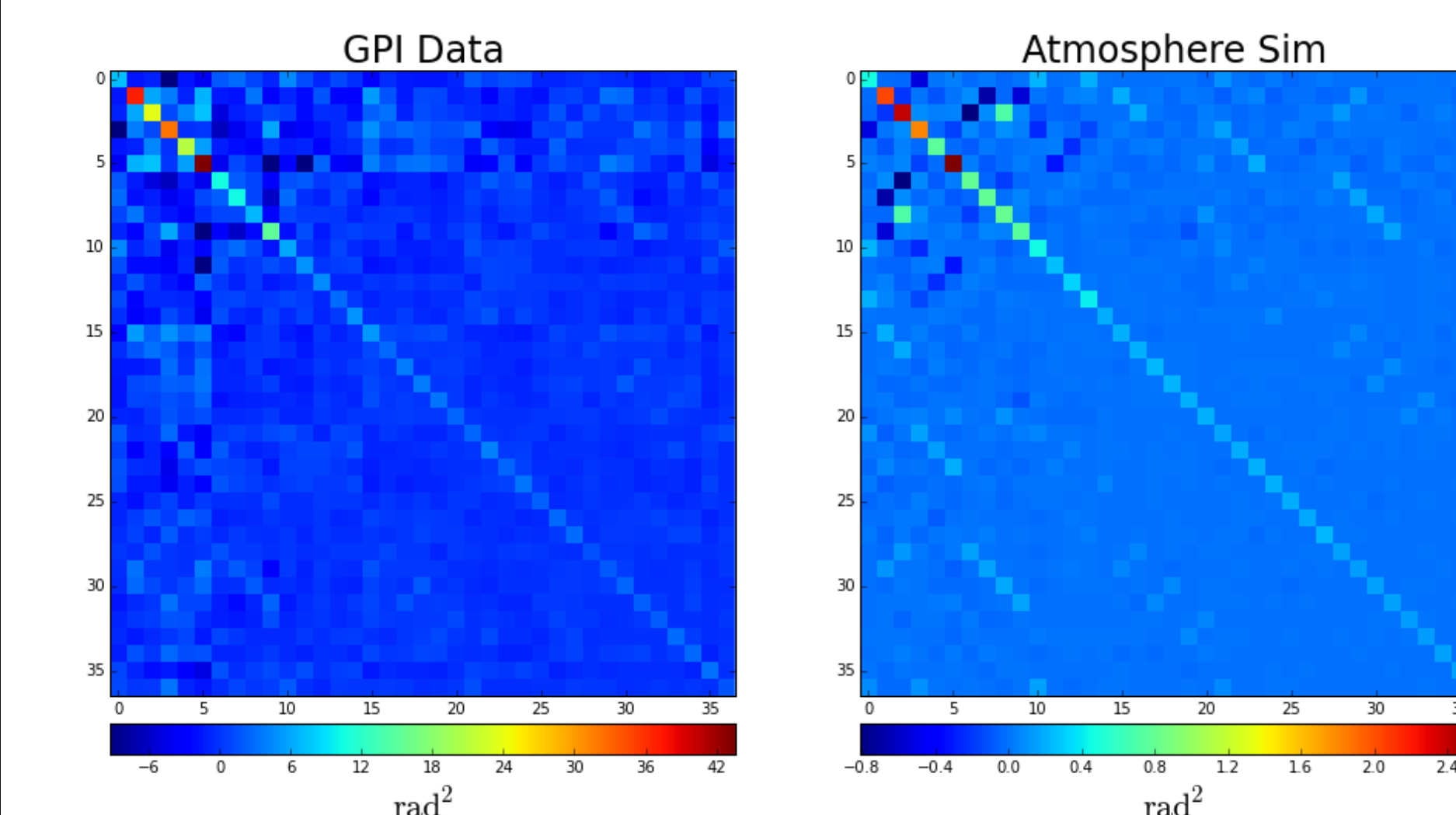


Figure 7 – Zernike covariances for a single dataset compared to the Kolmogorov turbulence simulation.

Future Works

Future work will aim to use longer time series phase maps to study the behavior of the Zernike fit coefficients over larger time scales. This will also allow for a measurement of how quickly the RMS of the averaged Zernikes decreases. Additionally, the non-Kolmogorov behavior will be studied and compared to other measurements of observing conditions, such as atmospheric seeing, to look for correlations.

Acknowledgments

Special thanks to my research advisor, Aaron Roodman, and Bruce Macintosh and the GPI collaboration for providing access to GPI telemetry data.